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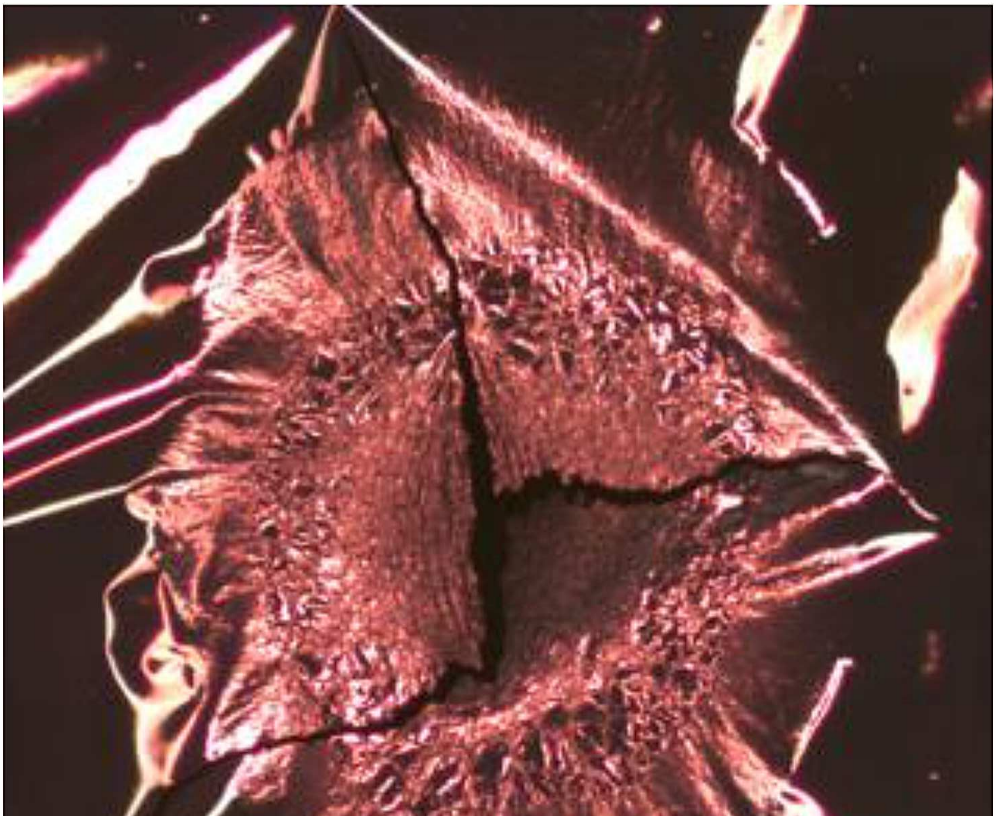
REPORT
June 2017

News and Reports from

High Energy Density generated by Heavy IOn and Laser Beams



The Plasma Physics Collaboration at FAIR - Report 2016

The cover picture shows a blossom-like structure created by the interaction of a high perveance He+ ion-beam from the NDCX-II induction accelerator (NDCX-II = Neutralized Drift Compression Experiment II) at Berkeley Lab with a 0.3-μm thick tin (Sn) foil. The structures in the foil are created by the energy deposition of the beam inducing melting of the tin by the ion-beam pulse and subsequent re-solidification and cracks from simultaneous rupturing of the foil by thermal stress. The energy deposition of the 1 MeV He+ beam was 40 mJ/cm2 and the field of view shown here is 6 mm.

With NDCX-II, intense ion pulses in the MeV range from an induction accelerator undergo plasma neutralization at the accelerator exit to compensate the high space charge and so enable strong focusing of the ion beam and high particle fluence at the target plane. Studies of the properties of matter range from heating with low intensity beams (negligible heating but collective effects) up to highest intensity heating of targets to explore the solid-liquid phase transition and in other experiments, high dose rate radiation effects on various materials and solid-state electronic devices. By choosing the beam-ion mass and the kinetic energy close to the Bragg peak, the energy deposition in the target (dE/dx) reaches a maximum and thin target foils are heated very uniformly. For other irradiation experiments peak particle currents of 2 A and 7 x 1010 He+ ions per pulse haven been achieved.

Find the contribution on NCDX-II by P. Seidl et al. on page 6 in this report!

(Cover text: P. Seidl and K. Weyrich)

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Editor: K. Weyrich

Co-editor: D.H.H. Hoffmann

Editorial

Dear Colleagues,

again this year the report is planned to be available at the upcoming workshop of our High Energy Density Physics Community at GSI/FAIR end of June 2017, where we also intend to finalize the formation of the new collaboration at FAIR/GSI that will be responsible for the planned future HED-science. A description of the future experimental research program is therefore in the first contribution on page 1 in this report.
As in the last years a large number of scientists from many countries worldwide responded again to our call for contributions to this report to demonstrate the strong growing interest in this research field in general and the desire to use intense high energy ion and laser beams to induce extreme states of matter. – The report period covers the research in 2016 and it will be published in June 2017, and the publishing year also comes up with a special anniversary. So let us take here the opportunity to congratulate the founding father of Plasma Physics at GSI – Professor Dr. Rudolf Bock – on the occasion of his 90^{th} birthday in May 2017!

The cover photo of this issue is from our colleagues at Berkeley who started with experiments using the intense beam from the upgraded NDCX-II facility. Also the so called sister facility of FAIR in Russia, NICA, is making considerable progress, while in China the plans for a High Intensity Accelerator Facility (HIAF) have matured and groundbreaking will probably start this year. From NIF at Livermore we get the report that experiments to control the capsule symmetry during implosion are continuing and show promising results.
In Korea the Kumgang laser facility reached a milestone in completing the main amplifier stages and demonstrating coherent beam combination, while laboratory astrophysics questions will be addressed in several other large scale Korean facilities under construction or already operating like PAL-FEL and RISP.

At GSI all scientists are preparing for the FAIR-Phase 0, which means that beam-time at GSI will be available again for experiments in 2018 after the upgrade of the SIS-18 and modification of the UNILAC. This is an absolute demand from all collaborations to prepare for the start of FAIR. The plasma physics community has a number of approved Technical Design Reports and the just recently approved one is the report for the PRIOR – high energy proton microscopy experiments. The new PRIOR-II proton microscope shall be ready at the experimental area HHT by 2019. This is a lot of work for the colleagues on-site at GSI as well as for the whole community. One has to consider that the experiments at HHT, where the previous HED/WDM research was performed, had to be adjourned for some time and the equipment there was not in use for quite a while during the shut-down that was essential at GSI to get the FAIR construction up to the current level.

Now we are looking forward to a busy year and wish all collaborating and participating teams the success they need.

Kind regards,

Dieter H.H. Hoffmann and Karin Weyrich

June 2017

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Stopping of relativistic projectiles by multicomponent plasmas

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Recently, the problem of estimating the energy losses of relativistic protons [1] has arisen, and the purpose of this note is to determine the relativistic corrections to the asymptotic form of energy losses by fast particles in a nonideal multicomponent plasma found within the method of moments [2].

This method allows determining the dielectric function $\epsilon(k,\omega)$ from the first convergent sum rules understood to be the power frequency moments of the plasma loss function

$L(k,\omega) = -\frac{1}{\omega} Im\epsilon^{-1}(k,\omega)$, defined as

$C_\nu(k) = \frac{1}{\pi}\int_{-\infty}^{\infty} L(k,\omega)d\omega\,, \nu = 0,2,4.$

The odd order moments vanish due the evenness of the loss function, and the even order moments are determined by the partial static structure factors of the system [3].

Relativistic corrections to the Lindhard formula were studied in [4] and, taking into account the canonical solution of the truncated Hamburger moment problem, the energy losses of relativistic particles in a hydrogen-like plasma with n_e=Zn_i can be written in the following form [5]:

$$-\frac{dE(v\to\infty)}{dx} = \left(\frac{Ze\omega_p}{v}\right)^2 ln\frac{2mv^2}{\hbar\omega_p\sqrt{1+H}} +$$

$$+\left(\frac{Ze\omega_p}{c^2}\right)^2 \int_{k_1}^{k_2}\frac{dk}{k^3}\frac{\omega_2^2\left(1-\frac{\omega_2^2}{k^2v^2}\right)\left(\omega_2^2-\omega_1^2\right)^2}{\Omega^4(k)+R^4(k)}, \qquad (1)$$

where $k_2 = \frac{2mv}{\hbar}$, $k_1 = \frac{\omega_p\sqrt{1+H}}{v}$, $\omega_2^2 = \omega_2^2(k) = \frac{C_4(k)}{C_2}$, $\omega_1^2 = \omega_1^2(k) = \frac{C_2}{C_0(k)}$, $R^2(k) = -ImT(k)$,

$\Omega^2(k) = \omega_p^2 + (\omega_2^2 - \omega_1^2)\left(1-\frac{\omega_2^2}{k^2v^2}\right) + ReT(k)$,

$T(k) = \omega_p^2\omega_2 Q^{-1}(k,\omega_2)$.

This result can be generalized to systems that are more complex. To this end, consider a beryllium multicomponent plasma, the composition of which was studied in [6]. Using this data, the relativistic corrections to the Lindhard formula were calculated using the loss function with an effective charge of the plasma ions,

$$Z_m = \sum_{j=1}^{4}\frac{N_jZ_j}{N}, \qquad (2)$$

where N_j is the number of j – fold ionized ions, Z_j is the corresponding charge number, and N is the overall number of system particles.

The results of calculations according to (1) are compared in Figure 1 to the modified asymptotic form of Bethe-Larkin (the first term of (1), dashed lines) [7].

The upper lines correspond to hydrogen plasmas, and the lower ones to Be plasmas.

In general, the target ions enhance the effect of stopping [8], but the Be ions are heavier then protons and this effect is somewhat weaker.

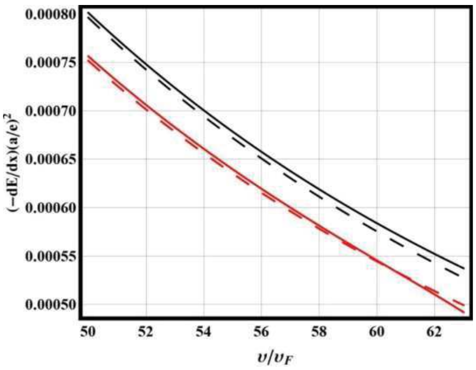

Figure 1 – Stopping power of H (two upper lines) and Be plasmas at *T=100 eV*, *Γ=0.24*, r_s *=1.13*.

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